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RESEARCH AND APPLICATION OF A NEW CHARGING FLOCCULATION AGENT FOR SMALL SCALE CLEAN WATER SUPPLY IN HA TINH AND VINH LONG PROVINCES, VIETNAM

Phung Chi Sy[1], Yoshiharu Yagyu[2] and Koichiro Harada[3]
[1]Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam
[2]Halvo Co. Ltd, Japan
[3]Japan Port Consultant Ltd, Japan
E-Mail: entecvn.pcsy@gmail.com

ABSTRACT

The charging flocculation agent is produced from volcanic ash by calcining it in the special firing furnace to generate high porosity, then applying a strong electric charge to some substances included in the ingredient of the ash by special processing. The agent consists of the natural inorganic substances, therefore, it is considered as an ecological water depurative. The agent has rapid rate of flocculation and sedimentation, therefore, the facility cost is cheaper, post-processing sludge is simplified, operation cost is low, and efficiency is high. Apart from effective treatment of the waters contaminated with high content of turbidity and color, the agent can remove some heavy metals such as Fe, Mn and some organic substances (COD), therefore, it have been used for water supply treatment. The results of application of the flocculation agent in Ha Tinh and Vinh Long provinces on small- and medium water supply facilities with capacity of 50 litters and 500 liters per a hour shows that the quality of the treated waters met the QCVN 02:2009/BYT. When using the flocculation agent and the disinfectant agent, the quality of treated waters can meet all 109 parameters regulated in QCVN 01:2009/BYT.

Keywords: charging flocculation agent, high turbidity and suspended solid, clean water supply.

1. INTRODUCTION

Vietnam has been in a stable economic growth since 1990's. In rural areas, however, income of local residents is still kept low. Contamination of ground water and river water with industrial discharges, pesticide chemicals, germs, etc. is a serious environmental problem. Vietnamese government has implemented several projects to improve national systems for safe water supply. However, percentage of the people, who have access to the safe water supply, is still limited at most 30% in the rural areas [1-2]. According to a doctor in the rural areas, who was interviewed in the last survey for ODA project formation, diarrheal disease is a major and chronic water-related disease and also a cause of second infections, such as dysentery, typhoid, etc. It is, in particular, serious problem for the babies with less resistance to the infections. Since 1986 the difficulties in finding a technology to treat wastes from coloring matter in textiles and from water-based paint manufacturing processes has been an issue for scientists in Japan. The waste which was not totally treated caused a serious pollution for environment. Basing on the fact of environmental pollution, Yagyu Ltd. in Japan has focused on researching the application of active coal and volcanic ash to treat the waste from coloring matter since 1990. After ten years of researching, until 2000, Yagyu Ltd. created a new flocculation agent based on activation of sand with charging (named "Kiyomaru" or "charging flocculation agent"). The flocculation agent was tested and applied to effectively treat the wastes from coloring matter in textiles and from water-based paint manufacturing processes. This agent is considered to be a ecological substance for its natural origin (made of sand, clay and volcanic ash) without chemicals; the agent which has affordable prices produces a big deposit in very short time (from about a few seconds to a few tens of seconds which is twice or three times faster than traditional flocculation agents); moreover, the deposit amount is small and tanks for deposit are not necessary to be big. In 2004 Yagyu Ltd. (as known as Yagyu Bosui Giken Corporation since 2003) introduced the agent to public. Since 2005 "Kiyomaru" has been sold in Japan as an water treating agent with turbidity and high content of suspending solid; the agent, in fact, has a big effect on treating wastes from water-based paint manufacturing that can not be treated by other traditional agents. The substance has been applied for the first time in two Chinese companies since 2008 [3]. From 2012 to the present, HALVO Company Ltd. in cooperation with Japan Port Consultants Ltd and Environmental Technology Center (ENTEC) funded by the Japan International Cooperation Agency (JICA) have implemented the study on application of "Kiyomaru" for small scale clean water supply in Ha Tinh and Vinh Long provinces [4-5]. Purpose of the JICA Project "Small Scale Safe Water Supply in Vietnam" ("3S Project") is to disseminate a special water treatment technique, which can produce the safe water at affordable cost for local people, and to establish proper management system and organization for sustainable operation of the safe water supply project by the local people. The paper presents some results on application of a new charging flocculation agent "Kiyomaru" for small scale clean water supply in Ha Tinh and Vinh Long provinces.

2. MATERIALS AND METHODS

2.1 Material

The charging flocculation agent "Kiyomaru" is a natural inorganic substance produced from volcanic ("Shirasu") by calcining it in the special firing furnace to generate high porosity, then applying a strong electric charge to some substances included in the ingredient of "Shirasu" by special processing. "Kiyomaru" consists of 24,7% Na, 11.5% Al, 19.6% Si, 0.1% P, 22.4% S, 1.8% K, 19,0% Ca, 0,9% Fe (Total 100%), which can consider as an ecological water depurative due to the following features:

- Highly Ecological: "Kiyomaru", which is composed of natural inorganic substances, is highly safe and easy to handle, so can reduce the environmental load;
- Cheaper Facility Cost: Its rapid flocculation response and sedimentation make it possible to downsize and save space of treatment facilities;
- Simplification of Post-processing: Floc after processing is strong, slightly viscous and easy to dewater. It is able to realize simplification of post-processing;
- Low Cost and High Performance: It is possible to ensure steady supply and quality of the products because "Kiyomaru" is mainly made from natural materials;
- Overwhelming Flocculation Capacity: The time required to flocculate is only 23 seconds. That's a overwhelming flocculation capacity and rate.

Apart from effective treatment of the waters contaminated with high content of suspending solid (up to 10,000 ppm), the agent can remove some heavy metals such as Fe, Mn, As, etc., odour and some organic substances.

The disinfectant agent used in the Study is calcium hypochlorite power with available chlorine concentration of 65-70%. HALVO Company Ltd. has integrated "Kiyomaru" with the disinfectant agent to create the water treatment agent called "HOH". The contents of "Kiyomaru" and the disinfectant agent can be adjusted for different water pollution levels.

Activated carbon is used in the Study in the case of the water contaminated by odour and some organic substances.

Filter set imported directly from Japan is used for removal of the suspended solid particles with fine size.

2.2 Technology and equipment

Medium-type water treatment facility with capacity of 500 l/h: Raw water from rivers, lakes and underground water are pumped directly to the flocculation tank equipped with an automatic stirrer. Then the weighted amount of HOH is mixed with the raw water for 5 minutes. After mixing, the sedimetation process takes about 10 minutes. Then the water will be automatically pumped to the activated carbon filteration tank to remove the suspended solid, odour and organic substances. Afterwards the water is pumped to a container, and finally go through a 3-level filter set before use. The formed sludge is discharged from the bottom of the sedimentation tank. The filters are backwashed by a part of clean water. The technology process diagram of medium-type water treatment facility is presented in Figure-1.

Small-type water treatment facility with capacity of 50 l/h: Raw water from rivers, lakes and underground water are pumped directly to the flocculation tank equipped with hand-running stirrer. Then HOH added to the tank by a specialized spoon is mixed with the raw water for 2 minutes. After mixing, the sedimetation process takes about 5 minutes. Then the water will be poured to the activated carbon filter to remove the suspended solid, odour and organic substances. Afterwards the water is poured to a vesel before use. The picture of medium-type water treatment facility is presented in Figure-2. The technology process diagram of small-type water treatment facility is presented in Figure-3. The picture of small-type water treatment facility is presented in Figure-4.

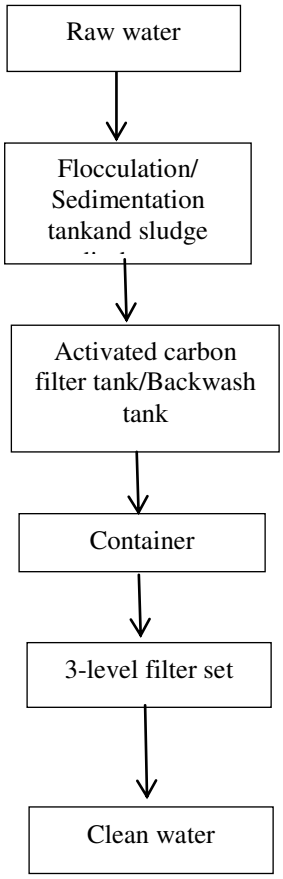

Figure-1. The technology process diagram of medium-type water treatment facility.

Figure-2. Medium-type water treatment facility.

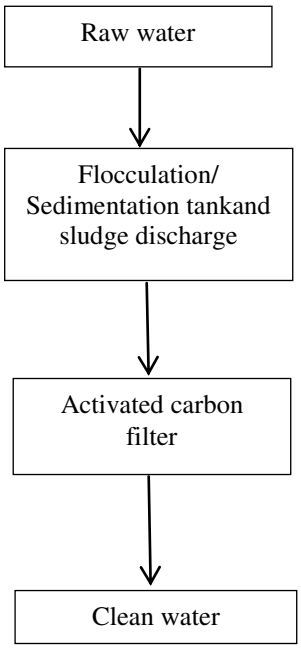

Figure-3. The technology process diagram of small-type water treatment facility.

Figure-4. Small-type water treatment facility.

2.3 Sampling and analysis method

The raw and treated water samples are taken from each facilities then preserved by the cold method and sent to Quality Assurance and Testing Center 3 (QUATEST 3) under Ministry of Science and Technology for analysis. The samples have been taken three times in October 2013, November 2013 and January 2014. The water quality parameters are analyzed based on QCVN 01:2009/BYT- National technical regulation on drinking water quality (QCVN 01) and QCVN 02:2009/BYT- National technical regulation on domestic water quality (QCVN 02).

2.4 The target locations of the Study

Target area of the Study is rural ones, where people have no access to the public safe water supply system, in Ha Tinh and Vinh Long provinces. Target group of the Study is vulnerable people, such as children in schools, patients in hospitals and lower-income residents (Tables 1, 2).

3. RESULTS AND DISCUSSIONS

3.1 Mechanism of flocculation, filtration and disinfection

The water treatment technology using "Kiyomaru" consists of 4 main processes: flocculation, sedimendation, filtration and disinfection (See Figure-5).

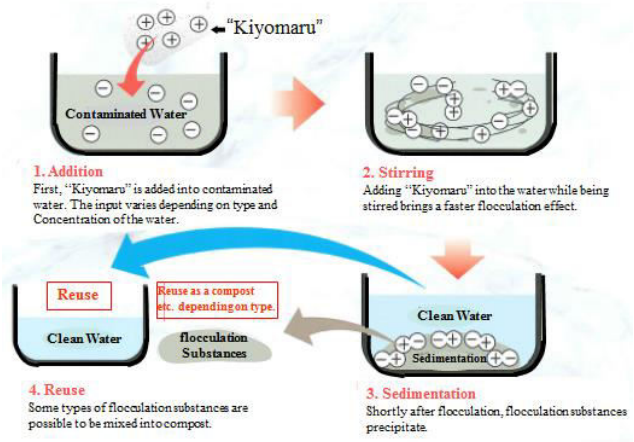

Figure-5. The mechanism of flocculation and edimentation processes.

The technology is descrided as follows:

a) **Flocculation:** "Kiyomaru" is added into contaminated water. In terms of running cost, the amount of "Kiyomaru" flocculant should be as little as possible depending on type and pollutant's concentration of the water. Adding positively charged "Kiyomaru" into the contaminated water, containing negatively charged solid particles while being stirred brings a faster flocculation effect to form electrically neural solid particles. Some heavy metals such as Fe, Mn, As etc. and organic substances can be removed by the adsorption processes due to high porosity of "Kiyomaru".

b) **Sedimentation:** Rapid floc formation is a key point because the larger floc makes a gravitational sedimentation process faster. Floc formation time of "Kiyomaru" is comparatively short, its floc is large and its rapid sedimentation makes filtration processing easy. Moreover, sludge after filtration in the case of using "Kiyomaru" is less clammy and possible to be dewatered in a shorter time than the one in the case of using other macromolecular flocculants.

c) **Filtration:** The activated carbon filter is used to remove the suspended solid, odour and organic substances by adsorption process.

d) **Disinfection:** Calcium hypochlorite power with available chlorine concentration of 65-70% is added to the water for disinfection.

3.2 Vinh Long province

The monthly record of the water treatment agent consumption in Vinh Long province from October 2013 to February 2014 is presented in Figure 6. Figure 6 shows that the water treatment agent consumption in Vinh Long province is varied from one to other location. The samples have been taken three times in October 2013, November 2013 and January 2014, then analyzed in the Quality Assurance and Testing Center 3 (QUATEST 3) under Ministry of Science and Technology. Summary of the analyzing results of raw and treated water samples taken at 10 water treatment facilities in Vinh Long province is presented in Table-3. The analyzing results of the raw and treated water quality (Table-3) shown that the average removal efficiencies of turbidity, color, permanganate index, iron, manganese, coliform, E.coli are 99.2, 89.5, 51.4, 93.6, 38.5, 80.6, 100%, respectively. Comparing the analyzing results of the treated water quality with QCVN 02:2009/BYT shown that concentrations of all parameters of the treated water in locations V1-V10 meet the technical regulation. Comparing the analyzing results of the treated water quality with QCVN 01:2009/BYT shown that concentrations of almost parameters of the treated water in locations V1-V10 meet the technical regulation, except the concentrations of permanganate index and coliform are higher than the regulations.

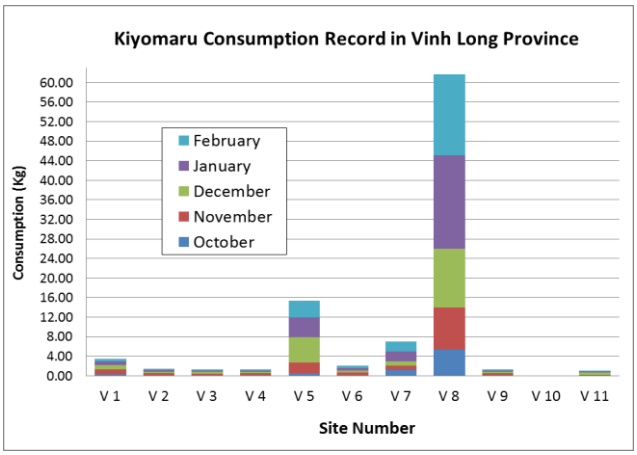

Figure-6. The monthly record of the water treatment agent consumption in Vinh Long province.

3.3 Ha Tinh province

The monthly record of the water treatment agent consumption in Ha Tinh province from October 2013 to February 2014 is presented in Figure-7. Figure-7 shows that the water treatment agent consumption in Ha Tinh province is varied from one to other location. The samples have been taken three times in October 2013, November 2013 and January 2014, then analyzed in the Quality Assurance and Testing Center 3 (QUATEST 3) under Ministry of Science and Technology. Summary of the analyzing results of raw and treated water samples taken at 11 water treatment facilities in Ha Tinh province is presented in Table-4. The analyzing results of the raw and treated water quality (Table-4) shown that the average removal efficiencies of turbidity, permanganate index, iron, coliform, E.coli are 100, 62.5, 57.7, 94.3, 100%, respectively. Comparing the analyzing results of the treated water quality with QCVN 02:2009/BYT shown that concentrations of all parameters of the treated water in locations H1-H10 meet the technical regulation.

Comparing the analyzing results of the treated water quality with QCVN 01:2009/BYT shown that concentrations of almost parameters of the treated water in locations H1-H10 meet the technical regulation, except the concentrations of coliform are higher than the regulations. Comparing the analyzing results of the treated water quality in location H8 with QCVN 01:2009/BYT shown that concentrations of all 109 parameters of the treated water meet the technical regulation [5]. The treated water can be used directly for drinking purpose

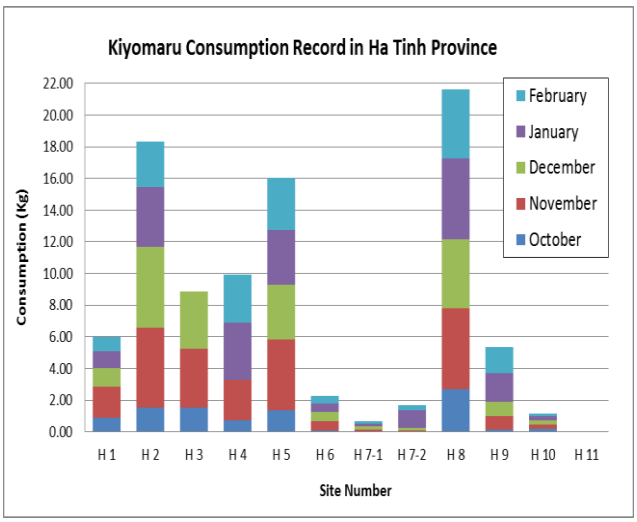

Figure-7. Biomass of Para grass in rainy and dry season (Harvested on the 24th of the survey).

Table-1. The target locations in Vinh Long province.

No.	Location	Facility	No.	Location	Facility
V 1	Sao Mai Kindergarten	Small	V 6	Trung Thanh Dong Medical Center	Small
V 2	Phu Loc Secondary School	Small	V 7	Quoi An Medical Center	Medium
V 3	Loan My B Primary School	Small	V 8	Tan Quoi Trung Commune Office	Medium
V 4	Son Ca 2 Kindergarten	Small	V 9	Ngai Tu C Primary School	Small
V 5	Trung Hieu Kindergarten	Medium	V 10	Nguyen TrungTruc Primary School	Small

Table-2. The target locations in Ha Tinh province.

No.	Location	Facility	No.	Location	Facility
H1	Phan Huy Chu Primary School	Medium	H6	Song Lap Kindergarten	Small
H2	Luu Vinh Bac Son Secondary School	Medium	H7-1	Vuong Loc Primary School	Small
H3	Loc Ha District Hospital	Medium	H7-2	Vuong Loc Secondary School	Small
H4	An Loc Primary School	Medium	H8	Phan Dinh Phung High School	Medium
H5	Nguyen Hue High School	Medium	H9	Bac Ha Kindergarten	Small
			H10	Thach Trung Primary School	Small

Table-3. Summary of the analyzing results of raw and treated water samples taken at 10 water treatment facilities in Vinh Long province.

No	Parameter	Unit	Raw water		HOH		QCVN 02	QCVN 01
			Range	Average	Range	Average		
1	pH	-	7.0-7.3	7.16	7.0-7.3	7.15	6,5 - 8,5	6,5 - 8,6
2	Odor	-	ND	ND	ND	ND	ND	ND
3	Turbidity	NTU	0-54	27.75	0-2.1	0.21	5	2
4	Color	Pt-Co	0-52.6	21.86	0-12	2.30	15	15
5	Total hardness ($CaCO_3$)	mg/l	60.8-92.2	69.95	67.5-105.0	81.59	350	300
6	Permanganate index (O_2)	mg/l	0-11.4	7.03	1.7-8.9	3.42	4	2
7	Chloride (Cl^-)	mg/l	5.3-39.6	14.21	10.8-42.6	17.11	300	250
8	Chlorine (Cl_2)	mg/l	ND	ND	ND	ND	0,3 - 0,5	0,3 - 0,5
9	Flouride (F-)	mg/l	0-0.6	0.24	ND	ND	1,5	1,5
10	Ammonium (NH_4^+)	mg/l	0-6.2	0.85	0-5.7	0.61	3	3
11	Total iron (Fe)	mg/l	0.05-2.3	1.25	0.04-0.18	0.08	0,5	0,3
12	Arsenic (As)	mg/l	0-0.004	ND	0-0.002	ND	0,01	0,01
13	Manganese (Mn)	mg/l	0-0.32	0.13	0-0.32	0.08	-	0,3
14	Nitrite (NO_2^-)	mg/l	0-0.7	0.11	0-0.2	0.02	-	3
15	Nitrate (NO_3^-)	mg/l	0-2.9	1.92	1.5-2.9	2.08	-	50
16	Sulphate (SO_4^{2-})	mg/l	9.3-39.1	20.20	46.6-127.8	85.34	-	250
17	Coliform	MPN/100 ml	1-520	31	1-22	6	50	0
18	E.Coli	MPN/100 ml	1-300	90	0	0	0	0

Table-4. Summary of the analyzing results of raw and treated water samples taken at 11 water treatment facilities in Ha Tinh province.

No	Parameter	Unit	Raw water		HOH		QCVN 02	QCVN 01
			Range	Average	Range	Average		
1	pH	-	7.1-9.3	7.84	7.3-8.2	7.78	6,5 - 8,5	6,5 - 8,6
2	Odor	-	ND-light odor	ND	ND	ND	ND	ND
3	Turbidity	NTU	0-93.7	9.26	ND	ND	5	2
4	Color	Pt-Co	ND	ND	ND	ND	15	15
5	Total hardness ($CaCO_3$)	mg/l	16.8-544.0	144.57	20.1-618.0	150.17	350	300
6	Permanganate index (O_2)	mg/l	0-25.3	3.33	0-4.2	1.25	4	2
7	Chloride (Cl^-)	mg/l	0-313.5	43.85	4.4-327.7	47.48	300	250
8	Chlorine (Cl_2)	mg/l	0-0.5	0.05	ND	ND	0,3 - 0,5	0,3 - 0,5
9	Flouride (F-)	mg/l	ND	ND	0-0.6	0.05	1,5	1,5
10	Ammonium (NH_4^+)	mg/l	0-2.2	0.24	0-0.8	0.07	3	3
11	Total iron (Fe)	mg/l	0.11-1.33	0.26	0.06-0.17	0.11	0,5	0,3
12	Arsenic (As)	mg/l	0-0.007	ND	0-0.004	ND	0,01	0,01
13	Manganese (Mn)	mg/l	0-0.65	0.08	0-0.61	0.09	-	0,3
14	Nitrite (NO_2^-)	mg/l	0-0.6	0.05	0-0.2	0.02	-	3
15	Nitrate (NO_3^-)	mg/l	0-45.4	5.02	0-42.0	4.93	-	50
16	Sulphate (SO_4^{2-})	mg/l	1.6-141,5	41.91	37.0-288.2	97.08	-	250
17	Coliform	MPN/100 ml	1-750	88	1-46	5	50	0
18	E.Coli	MPN/100 ml	1-10	2	0	0	0	0

4. CONCLUSIONS

Comparing the tesing results to QCVN 01:2009/BYT and QCVN 02:2009/BYT is shown that (1) The treated water quality in all locations V1-V10 in Vinh Long province meets the national technical regulation on domestic water quality (QCVN 02:2009/BYT). The people can use this water for domestic purposes; 2) Concentrations of almost parameters of the treated water in locations V1-V10 in Vinh Long province meet the technical regulation (QCVN 01:2009/BYT), except the concentrations of permanganate index and coliform are higher than the regulations, (3) The treated water in locations H1-H10 in Ha Tinh province meet the national technical regulation on domestic water quality (QCVN 02:2009/BYT). The people can use this water for domestic purposes, (4) Concentrations of almost parameters of the treated water in locations H1-H10 in Ha Tinh province meet the technical regulation (QCVN 01:2009/BYT), except the concentrations of coliform are higher than the regulations, (5) The treated water after treatment in loation H8 meet the national technical regulation on drinking water quality (QCVN 01:2009/BYT). The schooners can used this water for directly drinking purposes. Based on testing results of the treated water quality, it is recommend the Ministry of Health, Department of Health in Vinh Long Province and Ha Tinh Province to promulgate a notice to people in the locations of V1-V10 (in Vinh Long) và H1-H10 (in Ha Tinh) to use the water for domestic purposes. Particularly in H8, water after treatment reaches QCVN 01:2009/BYT; therefore schooners can drink the water directly.

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